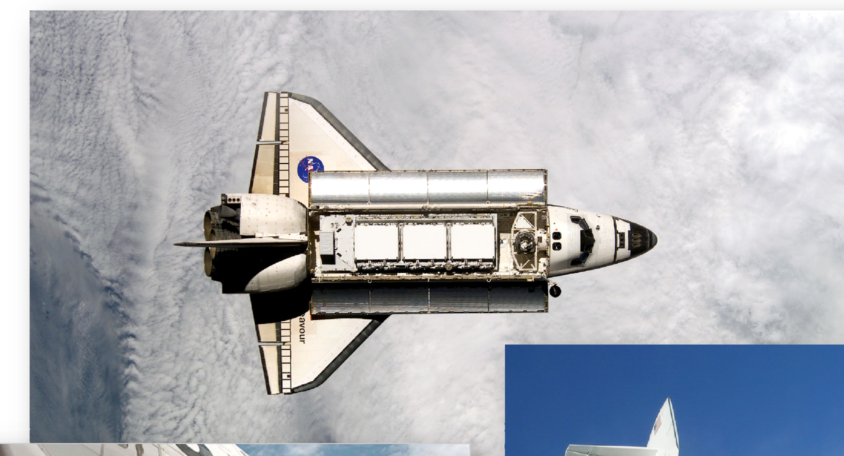
Prognostics for Structures

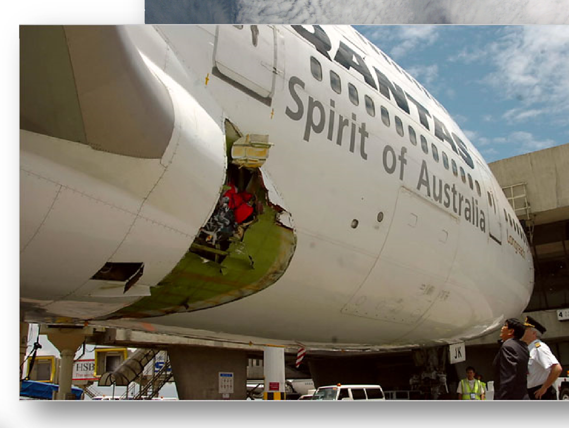
Prasun Bansal, Abhinav Saxena, Edward Balaban, Kai Goebel
Prognostics Center of Excellence, NASA ARC

Overview

Motivation

- Routine and expensive maintenance is required to detect damage due to impact, fatigue and corrosion on aircrafts
- Maintenance schedules are fixed for all aircrafts regardless of the conditions they are subjected to, and can be rationalized if a prognosis for the structure is known
- The problems are exacerbated with composites as unlike metals they have no visual signs of fatigue or impact damage
- Composites can loose upto 90% of their structural strength without any visible signs of failure (surface cracks, dents, surface elongation, etc.)
- Structural failures can be catastrophic





Objective

- Detect and classify incipient structural damage like cracks and delaminations
- Provide an accurate assessment of structural health and integrity
- Reliably estimate the Remaining Useful Life (RUL) for the structures
- Generate a real time action plan to avert a catastrophic failure or provide recommendations to extend RUL

Aloha Airlines B-737 flight 243

- The fuselage ripped apart during flight, just after takeoff
- Failure was caused by metal fatigue exacerbated by crevice corrosion

Boeing 787 Dreamliner

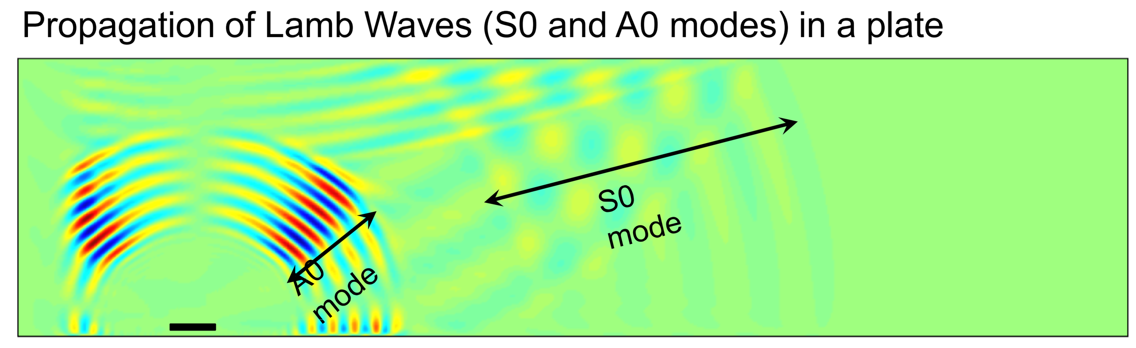
- It has an all composite body (fuselage, wings and control surfaces)
- A hammer drop during construction or maintenance on the composite body, could result in internal cracking and delamination, while leaving no signs of visible damage at the impact site

Methodology

Approach

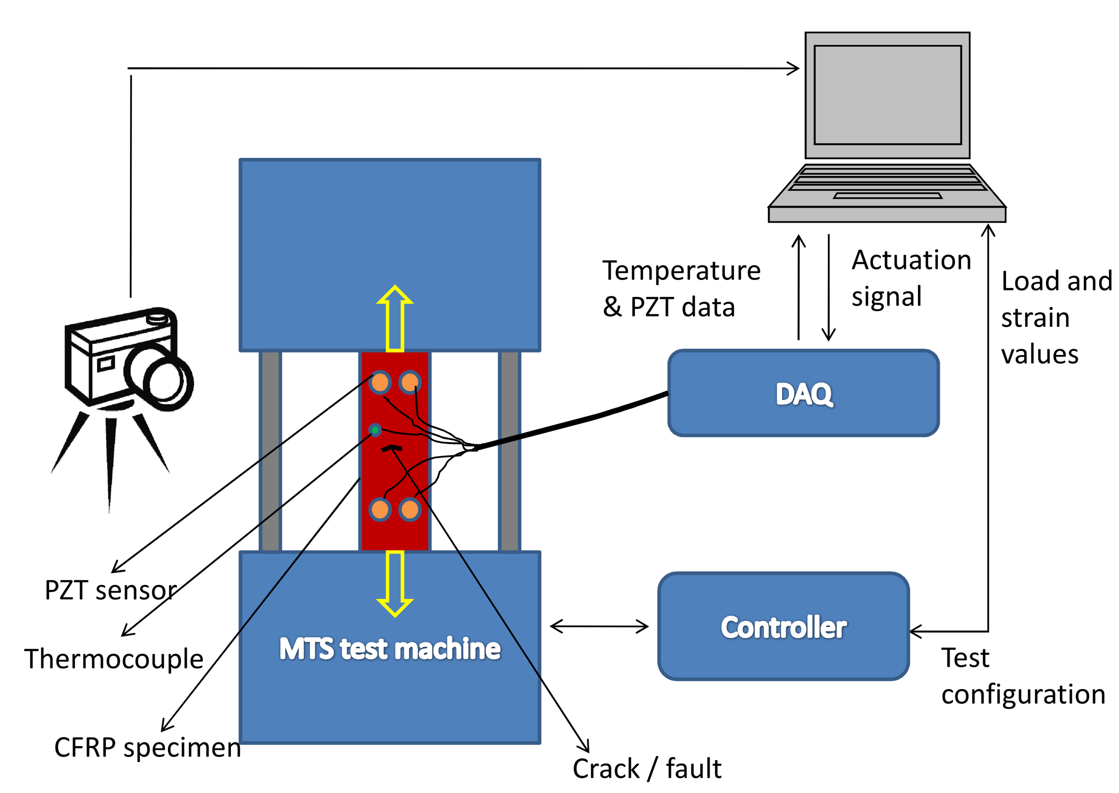
- Propagation of lamb waves through a structure changes due to any damage like cracks or delaminations in the structure which can be related back to the damage caused
- A combination of data driven and model based techniques are used to carry out the diagnostics and prognostics for the structure

Propagation of Lamb Waves (S0 and A0 modes) in a plate



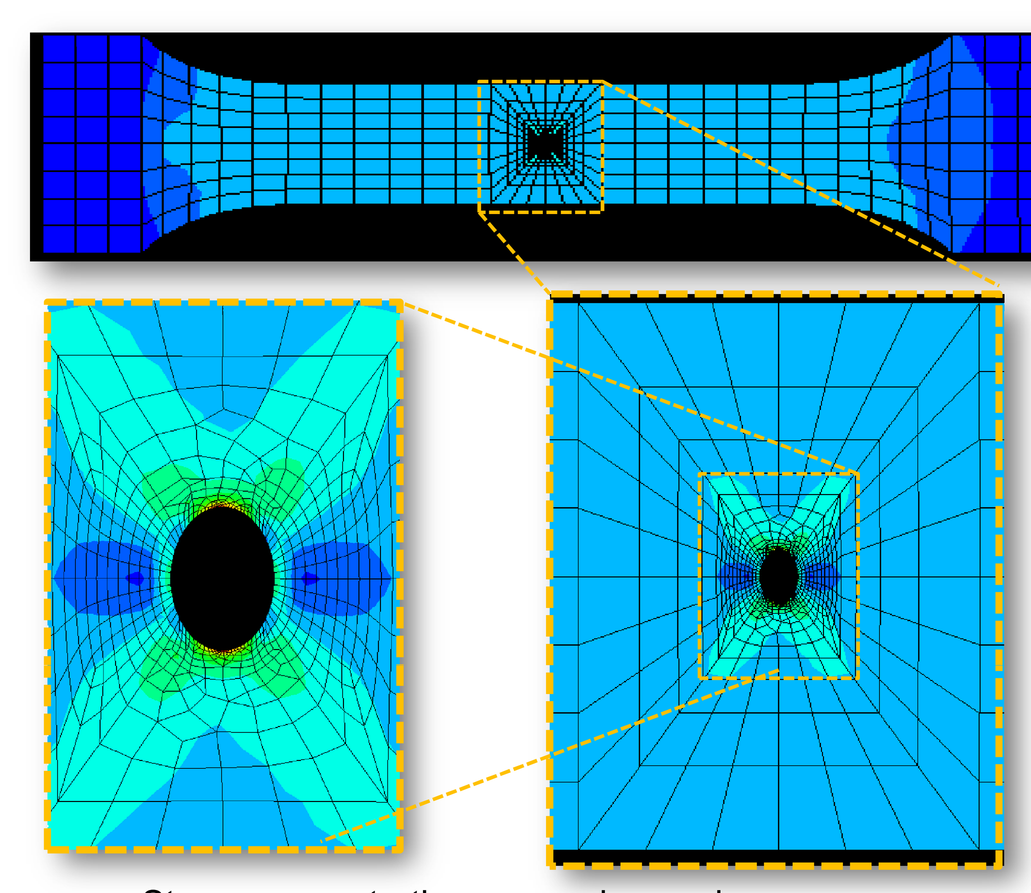
Experimental Plan

- Carbon Fiber Reinforced Plastic (CFRP) coupons of intermediate strength (T 700) with crack and delamination seeded in them, are subjected to uniaxial fatigue on an MTS test machine
- Piezoelectric (PZT) actuators/sensors are used to send/receive lamb waves through the coupons
- The data from the sensors is collected at a regular interval during the fatigue testing
- Visual data (photographs, X-ray) is also taken to confirm the size of the damage growth
- Temperature of the coupon is measured, to account for temperature related variations



Modeling

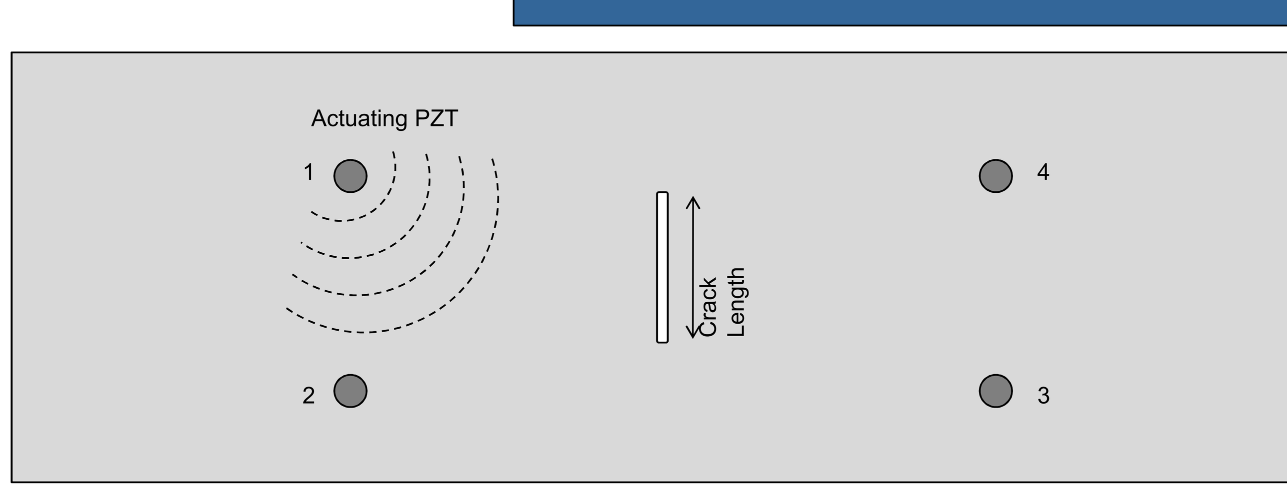
- A low order damage growth model based on Paris' law and collected data, is being developed
- The low order model will be validated by a finite element model with progressive ply failure and fatigue incorporated



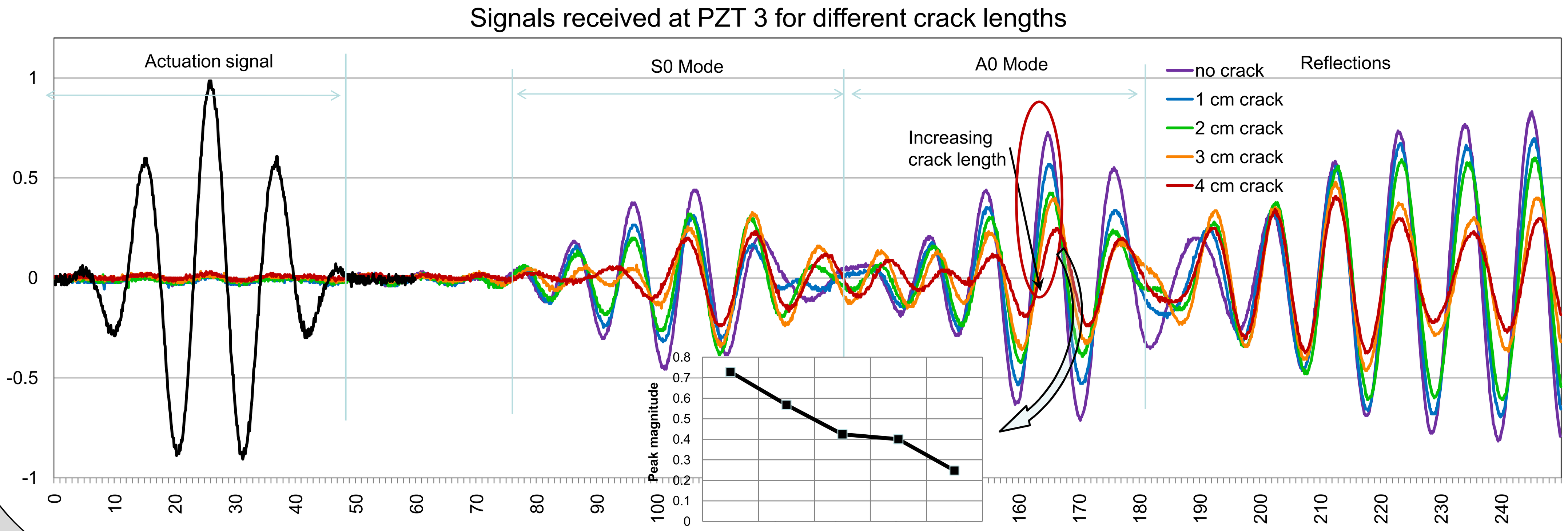
Stress concentrations around a crack

Results

- Preliminary tests were done on a 4"x12" Aluminum plate
- PZT 1 was actuated by a 4.5 peak sine burst modulated by a Hanning window
- Signals were received by PZT sensors at locations 2,3 and 4



Signals received at PZT 3 for different crack lengths



Prognostic Algorithm Development

- A robust diagnostic system will be developed as a foundation for prognostics
- The prognostics system will employ a variety of algorithms (Kalman filters, Particle filters, etc.) along with the low order damage growth model to estimate the current state of health and the RUL
- The influence of sensor noise and operational environment will be studied and incorporated into the prognostic system

Challenges

- Lack of general consensus on a theory for failure of composites
- Unlike metals, fatigue of composites is not well understood
- Damage (crack, delamination) propagation is highly non-linear
- Sensor placement for reliable detection of damage on a global scale poses problems
- Trade off between the number of sensors, their placement and cost needs to be addressed
- Methods for damage detection have to be automatic and non-labor intensive

POC: Prasun Bansal, ☎(650)604-1361, ✉ pbansal@arc.nasa.gov